ACTIVITY REPORT

May 2003

Natural Gas & Oil Technology Partnership

bringing department of energy national laboratories capabilities to the petroleum industry

Los Alamos
Los Alamos, NM 87545
(505) 667-7811

Sandia
Albuquerque, NM 87185
(505) 844-7333

Lawrence Livermore
Livermore, CA 94551
(925) 422-5196

Lawrence Berkeley
Berkeley, CA 94720
(510) 486-5085

Argonne
Argonne, IL 60439
(202) 488-2415

Brookhaven
Upton, NY 11973
(516) 344-3819

Idaho
Idaho Falls, ID 83415
(208) 526-7004

Oak Ridge
Oak Ridge, TN 37831
(865) 574-4941

Pacific Northwest
Richland, WA 99352
(509) 372-4565

To: William F. Lawson, Associate Director
National Energy Technology Laboratory
One West Third Street
Suite 1400
Tulsa, OK 74103-3519

From: J. Albright, Los Alamos
D.J. Borns, Sandia
J. Ziagos, Lawrence Livermore
N. Goldstein, Lawrence Berkeley
D. Schmalzer, Argonne
A. Goland, Brookhaven
B. Reynolds, Idaho
J. McFarlane, Oak Ridge
B. Saffell, Pacific Northwest

cy: E. Allison, DOE Fossil Energy
L. Capitanio, DOE Fossil Energy
G. Dehoratiis, DOE Fossil Energy
A. Hartstein, DOE Fossil Energy
B. Hochheiser, DOE Fossil Energy
E. Subia-Melchert, DOE Fossil Energy
N.B. Woodward, DOE Office of Science
D. Alleman, DOE-NETL-Tulsa
J. Casteel, DOE-NETL-Tulsa
N. Comstock, DOE-NETL-Tulsa
R. Lindsey, DOE-NETL-Tulsa
R. Long, DOE-NETL-Tulsa
K. Sterling, DOE-NETL-Tulsa
J. Ammer, DOE-NETL-Morgantown
D. Gurney, DOE-NETL-Morgantown
H. Guthrie, DOE-NETL-Morgantown
B. Gwilliam, DOE-NETL-Morgantown
J. Rogers, DOE-NETL-Morgantown
B. Tomer, DOE-NETL-Morgantown
F. Toro, DOE-NETL-Morgantown
M. Vargas, DOE-NETL-Morgantown

Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November	**February, April, June, August, October, December**
Drilling, Completion, and Stimulation Technology Oil and Gas Recovery Technology Diagnostic and Imaging Technology	Natural Gas Technology Upstream Environmental Technology Downstream Environmental Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: http://www.sandia.gov/ngotp/

Drilling, Completion, and Stimulation Technology

Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling

(Halliburton and INEEL)

Highlight:

- Second downhole source test series conducted.

The Capacitive Discharge Downhole Source (CDDS) and the Regenerative Combustion Seismic Source (RCSS) underwent a downhole source test series at the wells located behind the Idaho Research Complex in late March 2003. Two three-axis geophone strings were placed on the surface, extending radially outward from the source well. Several shots from each source were recorded at 10-ft-depth intervals to a depth of 73 ft.

The CDDS and the RCSS underwent a second series of downhole source tests using the same wells in early May 2003. This series included a tube wave suppressor located above each of the two sources as they were fired. The intent was to suppress the waves that excite a resonance in the well above the source. This well resonance tends to dominate the geophone response. The series also included shots fired directly into the surface, thus eliminating the well from the geophone response. In an attempt to capture the high frequency content beyond the bandwidth of the geophones, a hydrophone was used in place of one of the geophones.

Acoustic Telemetry (MWD)

(ABB, Electroacoustics Research Laboratory, Extreme, and SNL)

Highlight:

- Project report completed.

Researchers completed the writing of a comprehensive report on the acoustic telemetry project. It is undergoing internal review and is expected to be released within the next month.

Development of Chemically Bonded Ceramic Borehole Sealants

(GPRI, ANL, and LANL)

Highlight:

- Project completed.

Project is complete.

Coiled-Tubing Deployed Microdrilling with Real-Time, Downhole Monitoring

(DeepLook and LANL)

Highlight:

- Project completed.

A field operations report covering microhole drilling operations in 2002 was drafted, edited, and completed. The project is complete.

Effects of Well Conditions on Post-Perforation Permeability

(Halliburton, Penn State, and LLNL)

Highlights:

- High resolution X-ray computer tomography scans acquired.
- Evaluation and refinement of the perforation clean-up model continues.

Experiments completed recently at the Center for Quantitative Imaging at Penn State University and the Halliburton Jet Research Center are providing unique data with which to test the enhanced computational models. Researchers are focusing on the experimental program and refining the computational models to better predict experimental results.

Researchers acquired high-resolution X-ray computer tomography (CT) scans of five limestone cores perforated at Halliburton Jet Research Center at underbalances of 750, 1000, 1500, 2000, and 3000 psi. Unlike previously scanned perforations in Berea sandstone, the perforations in these cores show little dependence on underbalance.

The evaluation and refinement of the perforation clean-up model continued using recently completed flow tests, in which X-ray CT scans provided estimates of the radial distribution of post-perforation permeability.

Lifetime Performance Monitoring of Synthetic Fiber Mooring Ropes

(Petroleum Composites, Puget Sound Rope, Shell, Whitehill Manufacturing, and ORNL)

The project team met at ORNL in April to strategize on work for fiscal year FY2003. The immediate next step in the strain sensor system development is to complete the fiber integration methodology, including techniques for fiber ingress/egress in the rope assemblies. Whitehill Manufacturing will begin work on improved methods for inserting the fiber into a braided subrope; results of this effort should be available at the end of the next reporting period. The team expects to present a paper on project progress to-date at the Offshore Technology and Arctic Engineering Conference in June 2003.

Disposable Fiber Optic Telemetry System for Use With Coiled Tubing

(GTI, CTES, and SNL)

No report received.

Automatic Flaw Detection and Identification for Coiled Tubing

(U of Tulsa, INEEL)

This project is on hold until additional funds from DOE are received. Funds are scheduled to be in the August Fin Plan.There will not be a monthly report until the project starts again.

Laboratory Study on Borehole Stability and Sand Production in Weakly Cemented Sand

(ChevronTexaco, Shell, and LBNL)

No report received.

Development of Smart-Proppant Technology for Hydraulic Fracturing

(U of Tulsa, and INEEL)

Highlights:

- Representative microbiological systems and evaluation techniques selected.
- Methods developed to incorporate water-soluble compounds within Bio-Sep beads.

Work continues on the development of polymeric carrier systems for inclusion of industrial specified materials and systems. Additionally, representative microbiological systems were selected, as were evaluation techniques for enzymatic testing.

Organism growth is progressing. Year One activities at the University of Tulsa are nearing completion. The efforts concentrated on the development of Bio-Sep-based membrane systems for controlled release of desired chemically or biologically active agents. These activities include:

a. Fabrication methods for desired geometries;
b. Attachment/loading methodologies for desired active agents;
c. Facilitating time release of desired active agents;
d. Identifying analytical methods for evaluation of delivery systems; and
e. Bench testing of delivery systems.

Methods were developed to incorporate water-soluble compounds within Bio-Sep beads during fabrication. The release of these compounds from the beads is controlled to some extent by the molecular weight of the compound and the concentration of the compound inside the bead. The release rates can be

further increased or decreased by controlling the thickness and porosity of the bead's outer membrane during the fabrication process. A wide variety of compounds were and are being tested to create a database which can be used to predict bead properties required to produce a specific release rate of a given compound. Multiple compounds may also be incorporated in the beads.

Researchers are also investigating a system in which these compounds are reactants in a chemical reaction. The reaction could be used to generate a desired product (such as acid or a gas) at a desired rate. Experiments also indicate that Bio-Sep may be an outstanding immobilization matrix of enzymes.

Application of High-Powered Lasers to Drilling and Completing Deep Wells (GTI, PDVSA, Parker Geosciences, Colorado School of Mines, and ANL)

Highlight:

- Recent test confirms permeability increase in laser-drilled rock.

Recent advances in high-power laser technology provide a new tool to replace the current perforating gun for creating holes. The laser perforator has the flexibility of drilling holes with different sizes and shapes.

Increase in the permeability of laser-drilled rock was confirmed in a recent laser rock test. Three drilling methods were attempted. The goal of experiments was to drill a hole on rock as deep as possible using a series of laser bursts.

A continuous wave CO_2 laser beam at TEM20 was used. The purging gas was nitrogen, with flow rate of 275 cfh. Two power levels, 4000 and 2500 watts, and four rotary speeds were tested: 10,000, 5,000, 3,000, and 2,000 degree/min. At high power (4000 W) and low speed (3,000 degree/min), the laser beam intensively melted the rock and formed a glass phase that stayed in the hole. Increasing rotary speed reduced the melting at fixed power.

Optimal conditions were found at 2,500 W and 10,000 degree/min. A clean hole without any melting deposition was created at the optimal conditions. These optimal conditions were then applied to drilling of a deep hole in a 7-in-thick sandstone core sample. The 1/2-in-diameter beam with 1/4-in offset from the core center created a 1-in-diameter hole. The depth of the hole reached 3 1/4-in after a 45-second beam exposure, but the hole diameter was tapered from 1-in at the opening into 1/4-in at 3 1/4-in depth. This happened because the beam attenuation secondary effects increased as the hole became deeper. The hole became cone-shaped so quickly that rotary rock method did not work and the test was stopped at 3 1/4-in depth. Better purging system design and/or replacing the defocus beam with a collimated beam will be studied to drill deeper holes using this method.

In a second method, the rock sample was moved circularly by the workstation under the fixed vertical beam and purge gas tube. This generated a relative circular motion of a 1/2-in diameter defocused beam on the rock in a 1/2-in-diameter circle. A 1-in-diameter hole was formed by this circling beam after one revolution. A purging tube inside the hole circled together with the beam and was moved down after each revolution. The tube provided constant strong purging at the bottom of the hole as the hole got deeper. A 4-in-diameter by 6-in-thick limestone sample was lased by a circularly moving CO_2 beam. The beam power was 4000 watts and the gas flow rate was 300 cfh. The laser head was moved down 1/2-in between bursts. One burst is defined as one revolution that beam rotates. The beam moved 50-in per minute. A 1-in-diameter by 5-in-deep hole was made. Because of the large aspect ratio of 5:1, the hole became cone-shaped, with the bottom diameter reduced to 3/4-in.

Oil and Gas Recovery Technology

Measuring Sucker Rod Pump Parameters Downhole (Harbison-Fischer, UT-Austin, and SNL)

Highlight:

- New load cell installed at UT.

The new load transducer was installed below the stuffing box at the UT-Austin test well. This allows the stuffing box friction to be removed from the total polished rod load.

The internal flow area of a traveling valve was determined by filling the valve with water. The valve was placed on a balance and the weight recorded as a function of water height in the valve. This is much simpler than trying to determine the flow area from geometric measurements and drawings. Results predicted by pressure drops from the flow area determined this way will be compared with previous work to determine if this approach is better.

A pump instrumented with a compression chamber pressure transducer is being fabricated for Texas Tech.

Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling (ExxonMobil, Schlumberger, UT-Austin, and SNL)

Sue Minkoff, of the University of Maryland, Baltimore County, had an undergraduate student (Nick Kridler) complete a senior thesis on adaptive time stepping for loosely coupled flow and deformation modeling. The method used is called the Local Error Method, and while not tuned to this particular class of problem, it still shows a huge cost savings for the Terzaghi consolidation problem. This is because fewer mechanics steps need to be taken than with fixed step size. It is one of several methods being investigated for adaptively controlling the time stepping for coupled flow and geomechanics. Future work will compare the time stepping method to one based on pressure change.

Publication

S.E. Minkoff, C.M. Stone, S. Bryant, M. Peszynska, and M.F. Wheeler, "Coupled Fluid Flow and Geomechanical Deformation Modeling," *Journal of Petroleum Science and Engineering,* 38 (2003), pp 37-56.

Mechanisms of Oil Recovery and Validation of Corefloods (ChevronTexaco, ConocoPhillips, and LBNL)

No report received.

Direct Simulation of Near-Wellbore Mechanics (ChevronTexaco, Halliburton, Schlumberger, Shell, MIT, NM Tech, and SNL)

Research continued on the application of the 2D code and the implementation of the 3D code. In addition to the PI, contributing project staff included graduate interns Dave Boutt (NMT), Dave Farrell (Clarkson), and Scott Johnson (MIT), as well as postdoctoral associate Erik Strack.

At MIT, Scott Johnson completed his M.S. thesis, which is focused on the ellipsoidal discrete element approximation he is developing in collaboration with SNL through this project.

Hughes Christensen visited again in April to further explore the application of the modeling capability to their cuttings transport problems.

Researchers also held a two-day workshop for Halliburton (one of the CRADA participants) in May to assist them in the application of the project's 2D code to several simulation problems.

Efforts during this project period focused on two activities: 1) the development of 2D model specimens for the sanding simulations; and 2) the continued implementation and validation of the 3D fluid solver. One of the challenges in discrete element modeling is building synthetic materials that mimic the properties of real materials of interest (here, sand and sandstones). Researchers are trying to automate this model-building procedure with a series of scripts allowing the generation of discrete element models with variable particle shape and size distributions, as well as associated bulk properties. These models will be used in the sanding simulations to identify the parameters controlling sanding in the idealized 2D tests.

Validation of the D3Q19 lattice Boltzmann model was completed during this period. Researchers also began the implementation of the immersed moving boundary scheme used to couple the fluid solver with the discrete element model. Researchers are currently in the process of validating the moving boundary condition to verify that it is properly affecting the fluid flow around solids (discrete elements in the code) and computing the correct fluid forcing on solids.

Project Presentations / Publications

Cook, B.K. et. al., "Discrete Element Modeling Techniques," internal training workshop for Halliburton, May 22 - 23, 2003.

Cook, B.K. et. al. "Coupling Approaches for Discrete Element Methods and Fluid Solvers," internal briefing to Hughes Christensen Research, April 15, 2003.

Johnson, S., "Investigation of Efficient Geometric Shape Algorithms for Numerical Simulation of Discrete Particle Systems," MIT M.S. Thesis, May 2003.

Boutt D.F., B.J.O.L. McPherson, B.K. Cook, and J.R. Williams, "Fluid-Induced Fracture Initiation and Propagation in Geologic Systems: A Discrete Analysis," accepted for presentation at the 7th U.S. National Congress on Computational Mechanics, Albuquerque, NM, July 2003.

Johnson, S., J.R. Williams, and B.K. Cook, "Application of an Ellipsoidal Approximation for Discrete Element Modeling" accepted for presentation at the 7th U.S. National Congress on Computational Mechanics, Albuquerque, NM, July 2003.

Strack, O.E., and B.K. Cook, "Three-Dimensional Coupling of Particle Motion and Fluid Flow Using the Discrete Element and Lattice Boltzmann Methods," accepted for presentation at the 7th U.S. National Congress on Computational Mechanics, Albuquerque, NM, July 2003.

Cook, B.K., "Coupled Discrete Element and Fluid Flow Model with Applications to Wellbore Stability Problems," internal briefing to Hughes Christensen Research, January 23, 2003.

Cook, B.K., D.R. Noble, and J.R. Williams, "A Direct Simulation Method for Particle-Fluid Systems," submitted to *Engineering Computations*, 2003.

Boutt D.F., B.J.O.L. McPherson, B.K. Cook, and J.R. Williams, "Application of a Directly Coupled Numerical Model of Fluid-Solid Mechanics," accepted to *Soil and Rock America 2003*, 2003.

Johnson, S., J.R. Williams, and B.K. Cook, "Contact Detection Algorithm for an Ellipsoid Approximation for Discrete Element Modeling," submitted to *Engineering Computations*, 2003.

Well Integrity Assurance for Sub-Salt and Near-Salt Deepwater GoM Reservoirs

(BHP, BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil, Halliburton, Kerr-McGee, Shell, and SNL)

A bi-annual Partner's Meeting was held in Houston, TX on April 16 and attended by approximately 20 professionals from the eight participant companies. Recent work was reviewed and two new work areas were initiated.

The main work thrust on reservoir-scale finite element stress analyses (before drilling or production) is nearly complete. This work element is described in SPE 84554, recently submitted for the upcoming SPE Annual Technical Conference and Exhibition (ATCE) meeting to be held in October 2003. The report also presents some of the work results for a limited number of the idealized geomechanical models studied. Another manuscript is being submitted that describes development of a capability to visualize rotation of principal stress directions adjacent to salt bodies.

Two new work efforts are being initiated. The first relates to the identification of the governing geomechanics that define leak off pressures (LOPs) while drilling massive salt sections. The current industry practice is to limit the mud weight to the overburden pressure. However, significant cost benefit can accrue by better definition of LOPs in salt, as this affects the depth at which casing must be set. Detailed geomechanical analyses will be performed, and this effort will also integrate the finite element modeling already performed at the reservoir- and wellbore-scales. ChevronTexaco and BP released field data to the joint-integration project (JIP), including both leak-off test (LOT) and formation integrity test (FIT) data that will be critical to this effort.

The second initiative relates to an evaluation of salt composition and variability across the deepwater Gulf of Mexico (GoM), and implications for constitutive behavior. While the reservoir-scale modeling is not particularly sensitive to the specific constitutive salt model parameters (i.e., WIPP salt vs. Bayou Choctaw salt vs. Big Hill salt, etc.), the wellbore scale modeling is. This results from transient creep playing a significant role in the latter problem. Therefore, a program was designed to directly evaluate the variability in salt composition across the deepwater GoM. As part of their in-kind contribution, ExxonMobil will conduct a large suite of X-ray diffraction (XRD) analyses on cutting supplied from the industry participants, and BP will provide funding for additional tests to be outsourced. In addition, both ChevronTexaco and BP released pre-existing XRD data. The study was designed to include cuttings from a large number of wells across several areas of the deepwater GoM, multiple intervals for some wells, and multiple wells for some salt bodies. Each of the participants contributed cuttings, with some of the cuttings coming from record-setting wells such as the ConocoPhillips Spa Prospect.

Funding agreements to extend the project to Phase 2 for two additional years were negotiated and sent to each of the seven companies. Each company will contribute funding for an additional two years to complement the DOE FY03 funding received, as well as the continued funding anticipated for FY04.

Publications

Fredrich, J. T., D. Coblentz, A. F. Fossum, and B. J. Thorne, "Stress Perturbations Adjacent to Salt Bodies in the Deepwater Gulf of Mexico," *SPE 84554*, Proc. 78th Annual Technical Conference and Exhibition, Society of Petroleum Engineers, October 5-8, 1996, Denver, Colorado (14 p.).

Coblentz, D., R. M. Brannon, J. T. Fredrich, D. H. Rogers, and P. Crossno, "Imaging Local Stress Perturbations with a Tensor Visualization Algorithm Based on the Mohr Diagram," manuscript submitted to *Geochemistry, Geophysics, Geosystems* (June 2003).

An Integrated Approach to Assessing Seismic Stimulation (Aera Energy, ASR, BP Amoco, ChevronTexaco, ConocoPhillips, Halliburton, Marathon, OGCI, Piezo Sona-Tool, Schlumberger, Shell, UC-Berkeley, LBNL, and LANL)

Highlights:

- Core samples prepared and ready for experiments.
- Stress/strain measurement system calibrated.
- Invited article published in *The Leading Edge*.

A suite of new rock core samples were prepared for use in the LANL core stimulation apparatus. These include Fontainebleau sandstone with three different initial permeabilities, Burbank sandstone obtained from the Osage Project test formation in Oklahoma, and Vosges sandstone. Additional field samples from carbonate formations are also expected.

The improved stress/strain stimulation measurement system was fully implemented and initial calibrations using an aluminum standard are encouraging. The new system will track static and dynamic applied stress simultaneously and can be corrected for system nonlinearities.

An invited article, titled "Elastic Wave Stimulation of Oil Reservoirs: Promising EOR Technology?", co-authored by project PIs and Igor Esipov of Gubkin State University in Moscow, Russia, was published in the May 2003 issue of *The Leading Edge*. The article describes the current state of seismic stimulation research and knowledge and technology development related to enhanced oil recovery. Examples of research results from LANL, Russia, and LBNL are included, as well as a brief description of an international conference on the subject held last year in Moscow (expanded abstracts can be downloaded at http://www.ees.lanl.gov/Resources/dssl.shtml). The article represents a milestone in that the exploration geophysics community is gaining interest in this subject.

Direct Quantification of Uncertainties Associated with Reservoir Performance (ChevronTexaco and LANL)

Awaiting new funding. No work scheduled.

Diagnostic and Imaging Technology

Advanced Sensor Technology for Microborehole and Other Seismic Instrumentation (Input/Output and LANL)

Highlight:

- Downhole package built and installed in the San Ysidro test well.

A downhole package was built and installed in the test well at San Ysidro, NM. The package contains two standard geophones, as well as all the small sensors evaluated in the program to date. Hanging below the package was the hydrophone custom-made for this project. The package was installed in the well at a depth of 300 ft with the hydrophone submerged in water at a depth of 320 ft. In another well adjacent to the test well, a conventional geophone package was placed and the hole partially backfilled. A seismic line was shot and the data are being analyzed. Preliminary results show that the miniature sensors have a performance comparable to the standard sensors in the same package and to the buried geophones.

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters

(Amerada Hess, ChevronTexaco, ConocoPhillips, Fairfield Industries, GX Technology, Marathon, Unocal, and SNL)

Highlights:

- Amplitude vs. offset waveform is being prepared for presentation.
- New proposal designed to simulate the exact seismic reflection response of a subsurface geologic bed.

An AVO (amplitude vs. offset) waveform inversion research proposal is being prepared for presentation at the fall NGOTP Diagnostics and Imaging Technology forum. Analysis of seismic reflection amplitude vs. source-receiver offset distance is widely used in the petroleum industry to infer subsurface lithologic and/or pore-fluid properties. In particular, AVO is a valuable tool for discovery of natural gas reservoirs, and subsequent characterization of reservoir material properties. However, current AVO theory and practice adopt numerous simplifying assumptions which limit the full potential of the method.

The present proposal is designed to simulate the exact seismic reflection response of a subsurface geologic bed of finite thickness (including primary P- and S-reflections from both bounding interfaces, all internal multiples, and all mode-conversions) with a reflectivity or wave number integration algorithm. A search method will then seek the particular set of layer parameters (compressional and shear wavespeeds, mass density, attenuation factors, and anisotropic moduli) that reproduce the observed seismic data to a specified tolerance range. In preparation for this approach, the present nonlinear full waveform elastic inversion algorithm is being modified to incorporate a priori constraint information into the iterative inversion procedure. These "hard constraints" are designed to impose spatial uniformity on the recovered model parameters within selected subsurface units (as within an AVO target geologic bed).

Work also continues on preparing two presentations for the upcoming Annual Meeting of the Society of Exploration Geophysicists. One presentation describes the development of a novel finite-integro-difference numerical algorithm for simulating wave propagation within an anacoustic (i.e., attenuative and dispersive) fluid medium. This approach constitutes an alternative to the conventional "memory variable" technique for calculating synthetic seismic data in absorptive media. The other presentation involves computing several 3D elastic modeling examples for the SEG post-convention workshop, "Advances and Limitations in Numerical Modeling of Wave Propagation in Challenging Structures."

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP, BP Amoco, ChevronTexaco, ConocoPhillips, Core Laboratories/Tomoseis, ExxonMobil, Fairfield Industries, Fugro Geoservices, GeoCenter, Geophysical Development, GX Technology, Marathon, Mitchell Energy, Paradigm Geophysical, PGS, Shell, Unocal, Veritas DGC, WesternGeco, Society of Exploration Geophysicists [SEG], Stanford, U of Houston, LANL, and LLNL)

Highlights:

- New Wave-Equation Migration Velocity Analysis (WEMVA) method tested on 2D data set.
- Synthetic elastic data being computed for complex Marmousi II model.

Successful development of a new Wave-Equation Migration Velocity Analysis (WEMVA) method required developing a differential residual migration operator. The migration must overcome the fundamental limitations imposed by the Born linearization of the wave equation. The differential residual migration operator transforms migrated images into image perturbations that can then be inverted for perturbations to the velocity model. The inversion can converge to the correct velocity functions even if it is started from a poor initial solution.

Furthermore, researchers tested the use of a computationally inexpensive normal-incidence inversion of the image perturbations using the new WEMVA methodology and found that it still converges to the correct answer. Consequently, expensive prestack inversion is needed only in the final stages of the velocity estimation process. It can be safely substituted with inexpensive normal-incidence inversion in initial stages of the velocity estimation process.

The E3D elastic modeling code is being used to generate a synthetic seismic dataset for the 2D elastic Marmousi II model. This model is 1-km-long by 3.5-km-deep. The synthetic dataset mimics a full-length exploration survey with shots positioned every 25 m over a 12-km aperture centered over the model. Two arrays of receivers extend along the entire length of the model. The first array consists of geophones located just below the water surface, and the second array consists of multi-component seismometers situated on the ocean floor. In addition, synthetic data from a simulated vertical well, with an array of geophones that extends from the surface to the bottom of the model, is being generated. An energy absorbing free-surface is used as a boundary condition to suppress surface-ocean bottom multiples.

Rapid Imaging of Interwell Fluid Saturations Using Seismic and Multiphase Production Data

(BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil, JNOC, Landmark, RC2, Statoil, Tomoseis, Total-Fina-Elf, Texas A&M, and LBNL)

Highlight:

- Testing completed on three methods for inverting time-lapse amplitude changes.

Testing was completed on the three methods for inverting time-lapse amplitude changes (iterative, conjugate gradient, and quasi-Newton). The quasi-Newton and iterative methods were found to give the best convergence and reliable performances.

Researchers applied the iterative and quasi-newton approaches to the Bay Marchand time-lapse amplitude changes. Observed 3D time-lapse data were used to image permeability with the 7100 sand of the Bay Marchand reservoir. The algorithm converged quickly and in 12 iterations (reservoir simulations) researchers were able to match the time-lapse observations. Investigation results are being written.

Preliminary work on the inversion of time-lapse pressure estimates began. Researchers set up a test model and a preliminary inversion code based on the theory was developed. A set of time-lapse saturation and pressure changes for the Lost Hills oil field in California was obtained.The algorithm will be applied to these observations.

Offshore Oil Field Characterization with EM Methods

(Scripps, Texas A&M, and SNL)

Recent efforts of the Scripps/SNL marine electromagnetics team focused on supplementing NGOTP support through a) broadening the membership base of petroleum exploration/service companies within the Scripps Seafloor Electromagnetics Consortium, and b) responding to RFPs for marine hydrocarbon exploration. To further develop this program and establish a stable funding base for future research, design and implementation of the technologies made possible, in part, through NGOTP support, the Scripps/SNL team will also highlight its recent accomplishments in the exhibition hall at the upcoming annual Society for Exploration Geophysicists meeting. Among those topics to be highlighted is a demonstration of recently developed modeling capabilities for combined magnetotelluric and controlled-source EM interrogation of deep water hydrocarbon reservoirs.

Innovative Wave-Equation Migration

(Advanced Data Solutions, Amerada-Hess, Applied Geophysics Services, Baker Atlas, BHP, ConocoPhillips, ExxonMobil, Fairfield Industries, GX Technology, Petroleum GeoServices, Screen Imaging, Shell, TomoSeis, Unocal, Veritas DGC, and LANL)

Project researchers generalized the wave-equation migration methods to the offset domain. Then researchers tested it using impulse responses and synthetic datasets for the Marmousi model and a 2D slice of SEG/EAGE salt model.

The preliminary results demonstrate that the methods have the potential to produce more accurate images than those reported by others. In addition, researchers numerically implemented the recently proposed migration imaging condition to obtain images with clear physical meaning. The numerical examples for the SEG/EAGE salt model demonstrate that the reflection angles on reflectors in deep regions of the model are small (mostly less than 15 degrees), due to limited data-acquisition apertures.

Finally, researchers investigated applications of the wave-equation migration methods for cross-well datasets provided by a particularly interested industry participant of the project.

Testing and Validation of High-Resolution Fluid Imaging in Real Time

(DeepLook, KMS Technologies, KJT Enterprises, U of Wisconsin, LBNL and SNL)

No report received.

Autonomous Monitoring of Production

(Aera Energy, ChevronTexaco, SteamTech Environmental Services, TomoSeis, and LLNL)

Highlight:

- Complete communications and measurement system tested.

A field deployment in early May 2003 was used to install the satellite communications and control system tested during the previous reporting period. This system is housed in a self-contained trailer setting at the work site and all communications with the system are now through the satellite network. This arrangement greatly reduces the time and expense of travel to acquire data.

Researchers successfully tested the complete communications and measurement system by initiating all commands from California to set measurement parameters, initiate acquisition, stop acquisition, retrieve the data and shut down the system. The next step is to repeat this sequence in another month and to determine the reliability of the system.

Data processing began for the data mentioned above. This will provide the first comparison image (against the baseline from December 2002) for the expanded area of coverage.

Anisotropic Properties of Compacted Clay-Rich Rocks

(BP Amoco, ChevronTexaco, ConocoPhillips, and LBNL)

No report received.

Realistic Anisotropic Velocity Estimation in Complex 3D Environments

(BP Amoco, ChevronTexaco, ConocoPhillips, Kerr-McGee, Shell, TomoSeis, and LBNL)

Development of reverse time migration (RTM) for tilted transverse isotropic (TTI) media continues. RTM methods have virtually no dip limitations and are algorithmically robust with regard to strong velocity gradients. In addition, RMT appears to provide superior resolution as far as fault definition and clarity of reflector strength is concerned (Bedbar, et al, 2003, CSEG meeting; Yoon, et al, 2003). Current testing is based on a model of an exploration play provided by industry participants.

A new P-wave acoustic equation for TTI media was employed. The size of model is 19.7 km by 8 km. The 10th order finite difference scheme was used to solve wave equation. To save CPU time and memory, codes were rewritten in FORTRAN 90.

Researchers generated 35 synthetic shot gathers and performed an initial prestack migration. Most literature is about TTI migration only, comparing TTI migration with isotropic results. Researchers are now using the TTI synthetic data and a vertical transverse isotropic (VTI) acoustic wave equation to do prestack migration. This work is on-going and will quantify the effects of the TTI on the VTI migration.

Modeling with the P-wave anisotropic acoustic wave equation, researchers found "artifacts" that look like a diamond shape in snapshots of the wavefield. This so called "artifact" (Alkhalifah, 1998) is a shear wave (Grechka, et al 2003). Therefore, even when the shear wave velocity is set to zero in order to generate a pure P-wave field, a shear wave is generated due to the anisotropy. These shear waves have strong amplitude and very low frequency, causing the finite difference method to become unstable. To overcome this problem, researchers employed a high order FD algorithm. In addition, 8th and 10th order schemes were developed and tested.

Work continues on a 2.5D P-wave forward modeling code in TTI media. Researchers are developing a minimum computational domain base on the solutions of the Eikonal equations to provides the bounds within the mesh that are required for computation of each shot.

Joint Geophysical Imaging

(ChevronTexaco, Core Laboratories, Electromagnetic Instruments, ExxonMobil, and SNL)

No activity to report.

Partnership Office

In May 2003, the FY2003 funding arrived for the Partnership projects in the Upstream Exploration and Production technology areas. The highly rated projects can now progress into another year of technology development and transfer. The Partnership now awaits direction of how to maintain this collaboration amongst DOE, its national laboratories, and the oil and gas industry in the coming years.

Mike Hoversten of LBNL has taken over the Partnership representative duties from Norm Goldstein. Norm has served the Partnership in many ways over several years as both the LBNL representative and the Partnership co-chair. We thank him for is sage advice and direction over the last decade.